Chapter 1. Global Distillation: The Fate and Transport of Toxic Chemicals into the Arctic.

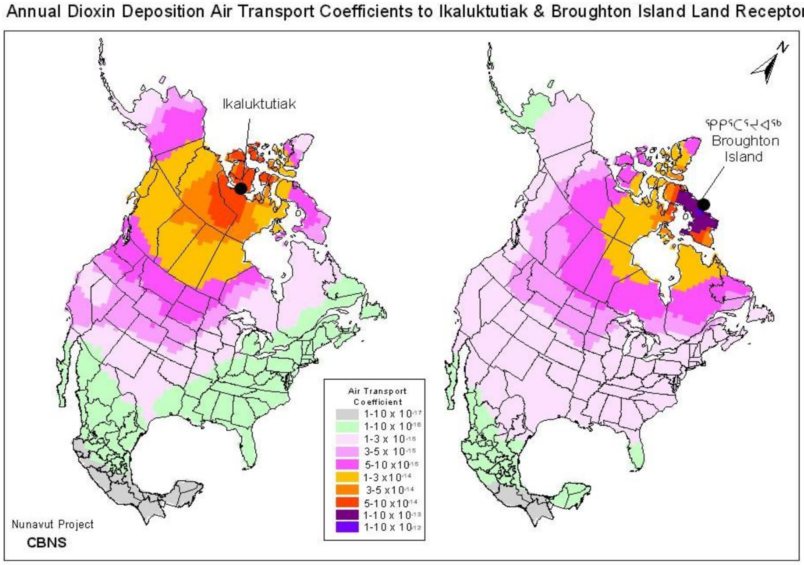
Background. There is a significant increase in pollutants being transported to and deposited into Arctic oceanic, atmospheric, terrestrial, and biotic environments, through a process known as ***Global Distillation***.

When persistent organic pollutants (POPs) are released into warmer climates, they evaporate and are carried back by winds to cooler areas, where they condense and descend back to Earth. These chemicals overwinter in soil, snow or water. When the summer sun re-vaporizes them, air currents blow them further toward their hemispheric pole. Then they drift downward once again. During this process, the various chemical contaminants are sorted: those substances that evaporate at the lowest temperatures keep re-vaporizing and are thus continuously drawn to the northern latitudes and higher altitudes. Finally in the Arctic, and similarly, the Antarctic, the toxins can no longer be uplifted into to the atmosphere. This is how the most pristine corners of the globe are becoming the most contaminated.[i]

Global distillation accounts for the transportation of toxic substances, through the air and water, and carried into our homes as dust. Poisons plowed, sprayed and dumped on the Earth are released, molecule by molecule, into the air, where they redistribute themselves back to the ground and into our food supply. Because of air currents, we each consume numerous toxic substances released into the environment by people far removed from us in space and time. Some of the chemical contaminants that we carry in our bodies are pesticides sprayed by farmers we have never met, whose language we may not speak, and in countries whose agricultural practices may be completely unfamiliar to us.[ii] The sad fact is that we are all exposed to environmental pollutants no matter where we live.

When it rains, we are all exposed to these contaminants. No local zoning laws can legislate against toxic fog, pesticide laced snowflakes, or even dioxin-contaminated raindrops falling into our local rivers, backyards and into our community reservoirs.

Annual Dioxin Deposition Air Transport Coefficients to Ikaluktutiak & Broughton Island Land Receptors



Pollutants transported across the Pacific Ocean, on the mid-latitude westerly winds, may be either particles or gases that may include coal combustion aerosols, pesticides, other persistent organic pollutants (POPs), and heavy metals such as mercury or lead.

Pollutant concentrations in snow, fish, wildlife, sediments, and Arctic Eskimos indicate that some of these substances, transported into and across the Pacific, have already been incorporated into wildlife, ecosystems and humans. A study on the Fraser River watershed in British Columbia concluded that toxic airborne pollutants from Asia may be a source of contamination in lake fish and sediments[iii]. Researchers have found extraordinarily high POP concentrations in the snowpack of mountains high in the Canadian Rockies [iv] and increased nitrates and sulfates in pristine streams in the Olympic National Forest on the coast of Washington State[v]. Other studies document pesticides in bald eagles of the Aleutian Archipelago [vi] and even brominated flame retardants up at the North Pole.[vii]

North Pacific and Alaska marine waters are perceived as pristine because most of Alaska's 6,640 miles (10,686 kilometers) of coastline are mostly devoid of point-source pollution, unlike most of the rest of North America. The greatest contaminant threat in Alaska comes from atmospheric and marine transport of contaminants from areas quite distant from Alaska. Pollutants are transported on mid-latitude westerly winds from Eurasia across the Pacific Ocean basin and into North America. The economic expansion around the Pacific Rim and in the rest of the world will deliver even more pollution to remote Arctic areas unless preventative measures are taken.

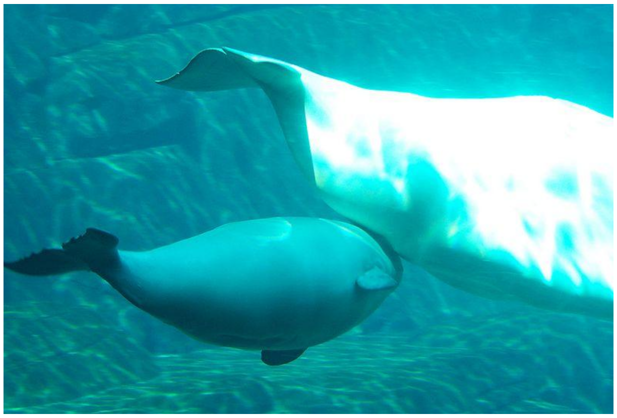
It is the geography of Alaska which makes it particularly vulnerable to volatilized contaminants transported by weather patterns from Asia. During the winter, Aleutian low pressure cells steer air from Southeast Asia into the eastern Bering Sea and the northern Gulf of Alaska (GOA), bringing precipitation along the way. When this air meets the mountains along Alaska's southern coast, more precipitation occurs, dumping entrained contaminants from the atmosphere into the marine ecosystem or coastal/interior ecosystems. Thus, pesticides applied to crops in Southeast Asia can be volatilized into the air, bound to suspended particulates, transported into the Alaskan atmosphere, and deposited via snow or rain directly into marine ecosystems or indirectly from freshwater flow to nearshore waters. Revolatilization of these compounds is inhibited by the cold temperatures associated with Alaska latitudes, resulting in a net accumulation of these compounds in northern habitats. This same distillation process also transfers volatilized contaminants from the atmosphere into the Pacific at lower latitudes, whereby ocean currents deliver the contaminants to Alaskan waters. Concentrations tend to be low in some places, but there are extensive geographical marine or land areas that act as sinks (cold deposit zones).[viii]

Exercise 1. The Chemical Burden in the Belugas of the St. Lawrence.

Background. From Lake Ontario, the Saint Lawrence River flows east along the US / Canada border, then turns north/ northeast where it travels through Montreal, then traverses Canada and eventually spills out into the Atlantic Ocean between Newfoundland and New Brunswick. Due to its geologic history as a major exit of glacial melt water during the last Ice age, it boasts one of the world's deepest and longest estuaries. Today, only about 650 beluga whales remain in the Saint Lawrence, of the thousands that once inhabited the region. This exercise will investigate one of the causes of the beluga population decline and the related human health effects of pollution in the Saint Lawrence.

Transitional cell carcinoma, a form of bladder cancer, was first discovered in beluga whales in 1985 during an autopsy of a beluga carcass that was washed ashore,[ix] followed by ductal hyperplasia, a form of breast cancer, found on numerous whales in 1988.[x] Soon after, 21 tumors were found on 12 belugas out of 24 stranded beluga carcasses.[xi] By 2002, 129 stranded carcasses had been autopsied and cancer was found in 27% of the whales, the same percentage as that found in humans living in the same area.[xii] In addition, the St. Lawrence belugas died at a much earlier age than their Arctic counterparts in northern Alaska.[xiii]

The St. Lawrence belugas were observed to have trouble reproducing. When chemical analysis of their blubber was conducted, a mixture of persistent organic pollutants (POPs) was found.[xiv] Dissolved in the whales' fat, were concentrations of some toxic chemicals at the highest levels ever recorded in a living organism. Two of the contaminants, PCBs and DDT,[xv] have a history of use in the St. Lawrence basin, but the pesticides chlordane, toxaphene, and mirex do not. Both toxaphene and chlordane are found in the waters and sediments of the estuary, but if they have no history of use in or around the St. Lawrence basin, where did they come from? The pesticide Mirex was once used in the southern US to control fire ants and is found neither in the water nor the silt of the estuary, and it is also not found in the bodies of any other marine mammal living in the estuary, only in the belugas.[xvi] How did the Mirex get into the belugas?



In addition to the POPs found in their blubber, the belugas have exposure to local pollution from aluminum smelters and other industries that line the St. Lawrence River basin. These industries contaminate the water with chemicals such as benzo [a] pyrene, which is a polycyclic aromatic hydrocarbon (PAH), a known carcinogen. Benzo [a] pyrene is seldom manufactured on purpose. It is created during the combustion of all kinds of organic materials from wood, to gasoline to tobacco. It also occurs in coal tar used to make creosote, a wood preservative, and pitch, used in roofing and aluminum smelting. Benzo [a] pyrene causes cancer by taking an oxygen atom from a body cellular enzyme that would normally detoxify and metabolize a harmful chemical invader. Once the cellular enzyme gives up the oxygen molecule, the benzo [a] pyrene is activated and has the ability to bond tightly to a strand of DNA, forming a DNA adduct. In this way, the chemical has the ability to produce genetic mutation and can become a crucial step leading to the formation of cancer. In addition, some PCBs also have the power to activate benzo [a] pyrene into a mutating carcinogen, which, if both toxins are present, can create a deadly interaction between the two chemicals and the host animal. DNA from the brain tissue of stranded beluga whales contain impressively high numbers of DNA adducts. These adducts are not found in belugas in more pristine Canadian estuaries.[xvii] Workers in nearby aluminum smelters also have an elevated form of the same type of cancers as the belugas. [xviii]

Investigation.

1. First research beluga whales. Their habitats, habits, food intake, migratory patterns and reproductive cycles. Then look more closely at the populations to determine if there are clusters of reported whale beaching and what were the suspected causes of death? Are there similar reports of human illnesses in the same areas?
2. Next find out the significance of the International Stockholm Convention and identify which pesticides and toxic substances were banned by this convention.
3. Discuss the toxicity and persistence of the POPs mentioned in the background text above.

4. What are the chemical pathways of the POPs within the body of mammals? How might they form cancers? (Look at the chemical benzo [a] pyrene in belugas as an example.)
5. How did the pesticides chlordane and toxaphene, which are both found in the waters and sediments of the estuary, get there, especially because they have no history of use in or around the St. Lawrence basin?
6. Discuss the bioaccumulation of toxic substances in the body fat of mammals.
7. What is the source of the pesticide Mirex? Remember, Mirex is found neither in the water nor the silt of the estuary,and it is also not found in the bodies of any other marine mammal living in the estuary, only in the belugas.
8. What can be done to reduce the exposure of belugas from toxins in the St. Lawrence?

Exercise 2. Bioaccumulation of Toxins in Native Arctic Eskimo Populations

Background. There is literally no place on earth that is not contaminated, from the farthest reaches of the Arctic to the depths of the ocean. Synthetic chemicals and pesticides are found in salmon, birds, whales, bears, and in the Alaskan Inupiat and Greenland Inuit people**.** The Inuit Eskimos, who live near the Arctic Circle, far from sites of manufacturing and sources of toxic chemical release, register some of the highest burdens of persistent organic pollutants and other toxins on Earth.[xix]

Although the Arctic looks pristine, contaminants are appearing in Alaska's air and water, and collecting in Alaska's fish and wildlife, including species of whales, seals and fish used by Native people as essential parts of their diet. The Arctic people are concerned for their health and the future of their fishing and hunting cultural. Yet this is not a problem caused by these people. The tremendous concentrations of pesticides and toxic pollutants in the Arctic are derived from contamination being transported throughout the Northern Hemisphere and accumulating in the Arctic.[xx]

Pollutant concentrations in snow, fish, wildlife, sediments, and Arctic inhabitants indicate that these substances have worked their way into Arctic biota, ecosystems and humans. A study on the Fraser River watershed in British Columbia demonstrated that toxic airborne pollutants from Asia are a constant source of contamination in lake fish and sediments in polar regions [xxi] [xxii]. The rising and falling movements of global distillation explains why chemicals used in SE Asian rice paddies eventually wind up in the bark of Arctic trees[xxiii], the skin of Arctic seals, and in the fatty tissues of Native Arctic Eskimos. Global distillation also explains why fish in the remote Canadian Yukon are so full of toxins, like the carcinogen toxaphene – a pesticide used in cotton fields. The toxic burden within these fish is so great that the Canadian government has placed bans on fishing in parts of the Yukon.[xxiv] This phenomena also explains why, during negotiations for the UN Stockholm Convention of POPs, the most powerful testimony came from a delegation of Inuit mothers as they spoke on ecological genocide. [xxv] [xxvi]

Many of the settlements of the original Arctic Alaskans are still inhabited, and they still depend on marine ecosystem as a major food source. Barrow is the northernmost settlement in the United States, with a population of over 4,000 (in 2006), Point Hope is the second largest community, with a population of over 700 residents, and Wainwright is the third largest community on the North Slope, with a population of over 500 residents. All three communities boast a majority of Inupiat residents who hunt caribou, bowhead, gray, and beluga whales, seals and fish, which are the community mainstays for subsistence.[xxvii] The extreme seasonality of production and short food chains, combined with the preferential atmospheric transport of some contaminants to the Arctic may cause long-lived, lipid-rich marine mammals and birds to bioaccumulate toxins which may threaten human health [xxviii].

The existence of organic contaminants in biological tissues means these contaminants are being transported within the food webs in Alaska fish habitats. The trophic structure of Alaska's marine food webs, coupled with the tendency of contaminants to accumulate in Arctic habitats, causes apex predators to concentrate significant amounts of POPs and other toxins in their tissues. Organisms occupying the top trophic levels in a food web bioaccumulate the highest concentrations of the contaminants. [xxix]

Thanks to global distillation and long Arctic food chains, the bodies of Native Arctic Eskimo populations have become repositories for chemicals produced and deployed throughout the northern hemisphere. A 2008 study of the Inuit found increased levels of DDT, PCBs and other POPs. Many of these chemicals are proven endocrine disruptors. [xxx]

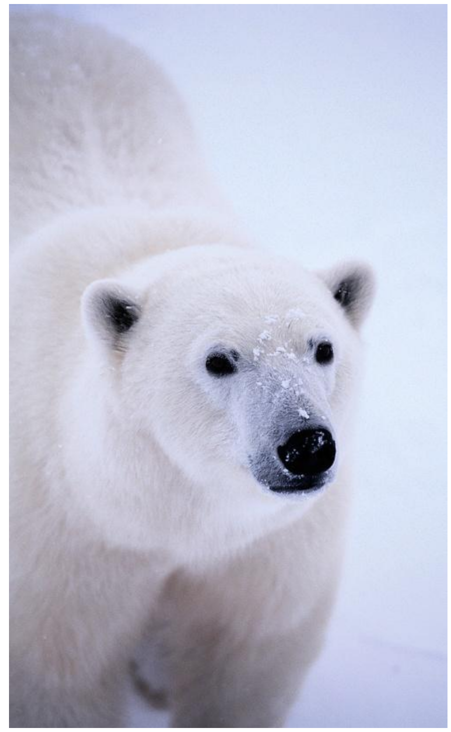
It is not surprising that other Arctic people are also showing similar trends. Studies in Canada have shown that PCB concentrations in the blood of adult Inuit people are seven times higher than adult populations in more southerly regions of North America. Studies of Native Arctic people in western and southwestern regions of Alaska also have a significant body burden of PCBs and DDT.[xxxi]

The contaminant loads experienced by Alaskan natives subsisting on foods derived from marine habitats have been measured. In one study, the total PCB concentration (not lipid adjusted) in serum collected from Aleutian men, ages 45 to 54, averaged 8.7 parts per billion (Alaska Division of Public Health 2003). By comparison, the concentrations in similarly aged men from around the Great Lakes who also consumed large amounts of fish (more than 52 meals per year) averaged 4.8 parts per billion [xxxii] [xxxiii]. The organochlorine toxins found in their bodies are endocrine disruptors and are linked with reproductive abnormalities in humans, animals and in both sexes. Here in the Arctic, twice as many girls, as boys have been born, and high levels of hormone-disrupting chemicals have also been found in the blood of Arctic women in villages from Russia to Greenland.[xxxiv]

The increasing levels of environmental pollutants in Alaska require attention because: a.) most of these contaminants do not originate in the Arctic and cannot be reduced through local action there; b.) the ecosystems of the Arctic frequently terminate with a large number of lipid-rich tertiary carnivores, which comprise a high proportion of the Eskimo diet, and; c.) Arctic residents, particularly those with a subsistence culture, may suffer serious health effects from these pollutants.

Investigation:

1. What is the Arctic Paradox?
2. Identify and research the POPs and toxic substances found in the whales and seals that are the mainstays of the Native Arctic Eskimo populations.
3. Why are the toxin levels so high in these species?
4. Discuss the Arctic food web and bioaccumulation process as it relates to the Eskimos.
5. How do these toxins affect the reproduction, behavior IQ, immune systems and behavior of mammals? Use studies to document your answer.
6. What are the cancer rates within the Inuit and / or Inupiat communities?
7. What can be done to reduce the body burden of toxic chemicals within Arctic populations?



Exercise 3. Impacts of Persistent Organic Pollutants (POPs) in Arctic Marine Mammals

Background. The Arctic is not as pristine as it looks. Contaminants are appearing in Alaska's air and water, and collecting in Alaska's fish and wildlife.[3] The unanticipated concentrations of pollutants in the Arctic are derived to a large degree from contamination transported around the Northern Hemisphere and accumulating in the Arctic.

The trophic structure of Alaska marine food webs, coupled with the tendency of contaminants to accumulate in polar Arctic habitats, causes apex predators to concentrate significant amounts of POPs in their tissues. Organisms occupying the top trophic levels in a food web bioaccumulate the highest concentrations of contaminants [xxxv].

Wildlife in the Arctic, such as eagles, sea otters and Steller sea lions in the Aleutian Islands are being impacted by the transport of toxins into their environment via Global Distillation. These animals have elevated levels of the pesticide DDT and high levels of hexachlorocyclphexane (HCH). These pesticides are found in male Alaskan polar bears, while sea ducks, walrus and caribou have been tested finding high levels of cadmium in their bodies. Killer whales in the North Pacific are now considered the most contaminated mammals on earth with high levels of PCBs and other POPs.[xxxvi] For example, the total PCB concentration in seal-eating killer whales sampled near Kenai Fjords National Monument was one to two orders of magnitude greater than fish-eating killer whales, indicating the significance of their trophic position[xxxvii].

The existence of organic contaminants in their biological tissues means that these contaminants are being transported within the food webs throughout Alaska fish habitats. [xxxviii]

A second contributing factor to increased contaminant loads among apex predators in Alaska is their relatively long life. Contaminant loads increase with age in fish, [xxxix] Steller sea lions, [xl] and humans. [xli] Female pinnipeds in the Eastern Bearing Sea and northern Gulf of Alaska typically begin reproducing at 5 years of age,[xlii] allowing plenty of time for the significant accumulation of contaminants, especially because pinnipeds eat relatively large (i.e., old) prey. For example, the pollock consumed by Steller sea lions averages 1.3 feet (393 mm) and Atka mackerel averages 1.06 feet (323 mm). [xliii] This translates to fish ages of approximately 3 to 5 years old.

Contamination is probably widespread among forage species at low levels, but apex predators are likely to be the most affected as a result of their longevity, fatty lipid storage, and the relatively high concentrations they bear. In mammals, it is most likely that lipophilic (fat-loving) contaminants would have the greatest impacts on their first-born young. The accumulation of contaminants in females increase with age, but decrease after females reaches reproductive age. This is the result of their transfer of contaminants to their offspring in milk. This process has also been reported in sea lions, fur seals [xliv], and humans.[xlv]

Contaminants of most concern are the persistent organic pollutants (POPs) and heavy metals. POPs such as DDT, PCB's and dioxins are persistent, have a broad range of deleterious effects, and are clearly accumulating in the Arctic. This is surprising because POPs are not manufactured in the Arctic and were infrequently used in the region. In fact, many of these man-made chemicals have been banned for many years in the US, Canada, and several European nations. POPs may travel long distances from remote areas including Russia, Asia and North and South America, and particularly from countries where these substances are still used.

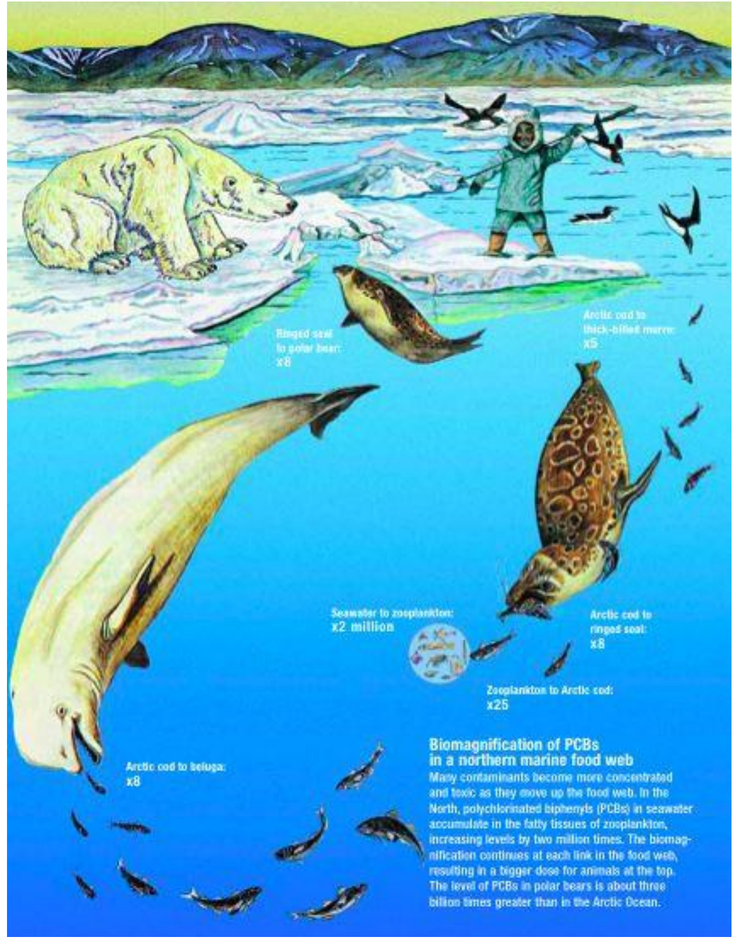
Organochlorine (OC) levels in the liver and blubber of 20 bowhead whales (*Balaena mysticetus*) collected during the Eskimo harvest at Barrow, Alaska in 1992 and 1993 were measured. Liver DDT (lipid weight) was significantly greater in male whales than in females. The organochlorines measured were at higher levels in older than younger males.[xlvi]

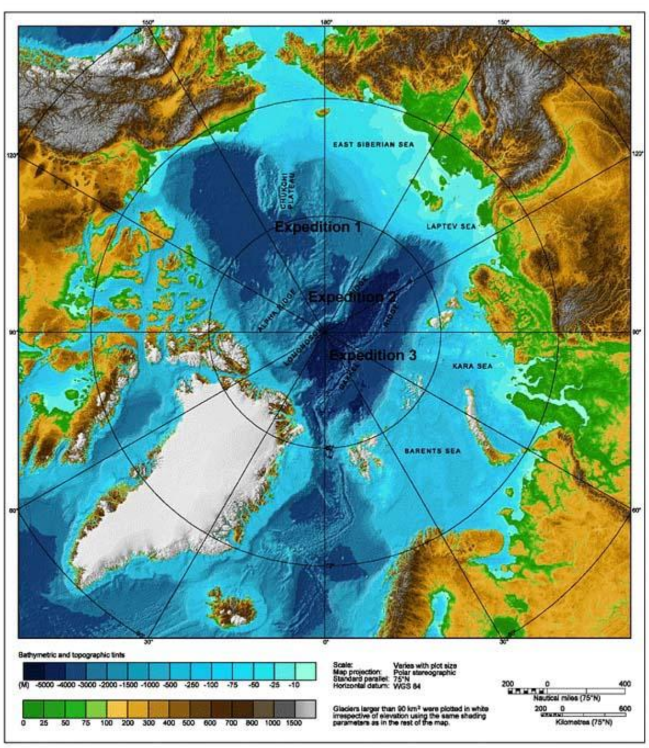
Scientists have found detectable levels of polychlorinated biphenyls (PCBs), DDTs, and other pesticides in the tissues of adult sockeye salmon returning to the Copper River[xlvii]. These fish apparently concentrated these contaminants in their tissues during their migration in the northern Gulf of Alaska (GOA) and delivered them to their spawning habitats in the interior of Alaska. Raptors and mammalian predators of these fish would further distribute these contaminants up the food chain. Very high polychlorobiphenyl (PCB) concentrations have also been found in some Pacific Northwest orca populations [xlviii].

The mechanism by which contaminants are delivered to the Alaskan marine environment guarantees that the contaminants will be found in Alaska waters for as long as they are released. [xlix] For example, the types of PCBs found in seals from sites near the Russian coast are consistent with those used in Russian electrical equipment. [l] Polybrominated diphenyl ethers (PBDEs) also appear to be increasing in marine mammals [li] and may surpass PCBs as the most prevalent POPs in arctic habitats.[lii]

A good demonstration of global transport into northern latitudes is the presence of dichloro-diphyl-trichloroethanes (DDTs) in the blubber of ring seals in the western Canadian Arctic. [liii] DDT and its congeners were first observed in these seals during the early 1970s. The persistence of DDT in these seals through the 1990s, despite North American bans on DDT use in the1970s, is evidence of continued deposition of DDT from countries still using this pesticide.[liv]

Another pesticide, Endosulfan, has also been widely used on cotton and salad crops since 1954. Like DDT, endosulfan is an endocrine disruptor and blocks testosterone. It is also highly toxic, bioaccumulative and capable of long distance transport. Endosulfan applied on southern cotton fields can end up in the fat of arctic seals and fish. It is already banned in the European Union and in 20 other countries. The US, however, still uses 1.4 million pounds of endosulfan on tobacco, tomatoes, fruits and vegetables half of which is applied in California. Although endosulfan is no longer produced in the US, it is still imported, causing leaders of Arctic tribal governments to protest it's continued use in the US. The EPA has banned home and garden uses of endosulfan, and has determined that it posses unacceptable residues in food and water supplies, however, it has been allowed it to stay on the market. In testing endosulfan for carcinogenic properties, the animals in one test all died before tumors could even form. [lv]

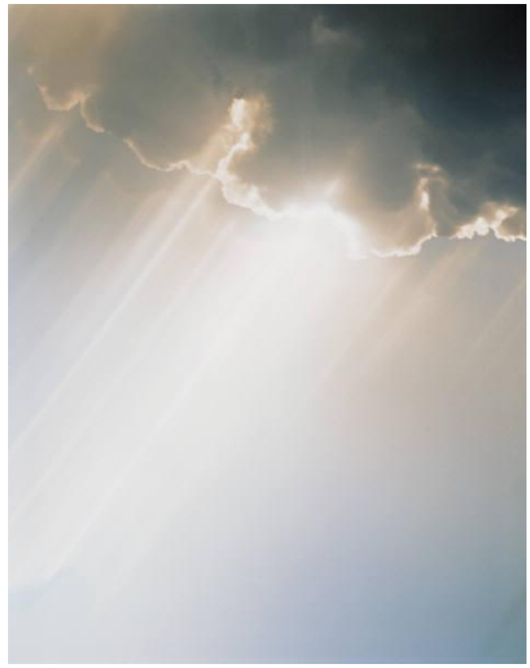




Investigation.

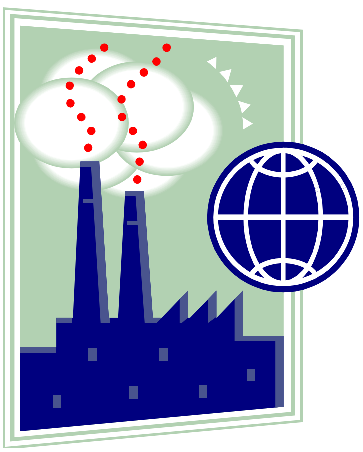
1. What are POPs? Define persistence as it relates to fate and transport.
2. Select one species of arctic marine mammal that is an apex predator.
3. Discuss the patterns of migration and reproduction along with habits and habitats.
4. Select at least two POPs found in the Arctic and in your selected species.
5. Trace the potential path of sources of the toxins and bioaccumulation within the food web: from potential primary producer on up the food chain to your species.
6. Define and discuss the Arctic Paradox. Can this phenomena be stopped or reversed?
7. If so, how? Identify and discuss at least two ways to reverse this trend.
8. Why is International cooperation essential for the survival of marine mammals in the Arctic regions?

Exercise 4. Atmospheric Dust: What is in the Air we Breathe?



Background. Pesticides and other POPs do not always stay on the fields where they are sprayed. They evaporate and drift up into the air. They dissolve in water and flow downhill into streams and creeks. They bind to soil particles and rise back into the air as dust. They hover over us in clouds then they fall as rain, fog, sleet and snow. They blow in the wind and are redeposited in backyard swimming pools, bird baths, reservoirs, glacial aquifers and enter the groundwater we drink. Little is known about how much goes where, but these toxins do wind up everywhere.[lvi]

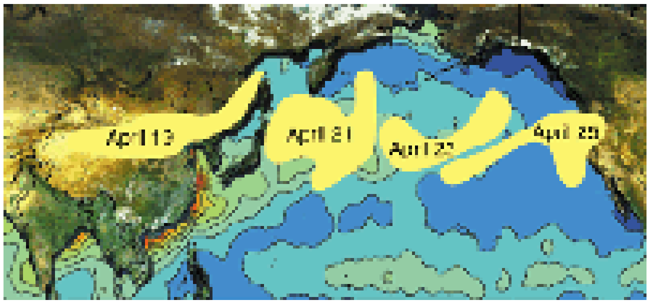
Many of the substances banished decades ago, such as DDT and PCBs, have not quietly faded away. PCBs are still present in virtually every household dust sample ever tested.[lvii] A 2009 national survey of pesticide residues in homes across the US found traces of DDT on 42% of kitchen floors.[lviii]



Global distillation is the explanation for these dangerous toxins entrained in our air and water and carried into our homes as dust. Poisons sprayed, plowed and dumped on the Earth are released, molecule by molecule, into the air, where they redistribute themselves back to the earth and into our food supply. Because of air currents, we are all exposed to toxins released into the environment by people far removed from us in space and time. Some of the chemical contaminants that we carry in our bodies are pesticides sprayed by farmers we have never met, whose language we may not speak, and in countries whose agricultural practices may be unfamiliar to us. [lix] The sad fact is that we are all exposed to environmental pollutants equally.

If you live in New England, your family is breathing the secondhand smog that forms each summer over cities across the nation, particularly in the Midwest, and then moves across the country to the Northeast, picking up additional pollutants as it travels. If you live in a city, eventually you and your children's lungs will be blacker than the lungs of country dwellers. Your family is inhaling soot, the mixture of particles rising from the inefficient combustion from diesel motor vehicles, residential heating, tobacco, power plants and incinerators. Soot particles can be very tiny, only 2.5 microns, so they can easily be inhaled and lodge deep within the lungs. These particles also wind up in the food chain, so they can be ingested as well as inhaled. [lx]

Diesel fuel exhaust, from school busses for example, is



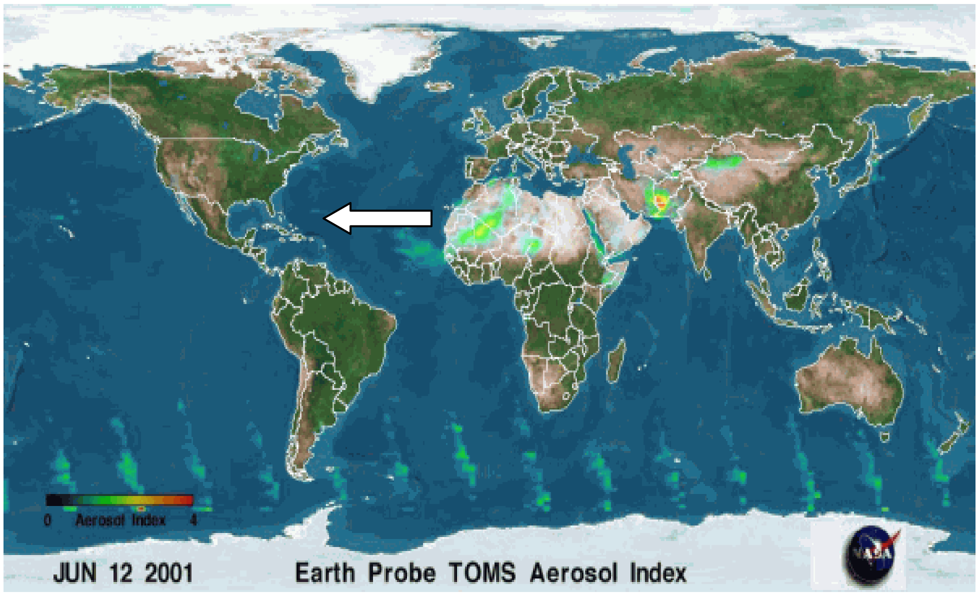
made up of 40 toxic chemicals, including benzene, butadiene, formaldehyde and other harmful products. In New York City, idling school busses spewed 1.3 millions of tons of soot and 60 tons of nitrogen oxides into the city's air, in just one year.[lxi]

Another example of soot, soil and dust being transported over long distances is the particulate matter which has been observed at Mauna Loa Observatory in Hawaii for over 30 years. High concentrations of anthropogenic (man-made) pollutants including sulfur, black carbon, and enriched trace metals were measured in this dust. Pollutant outflow from the Asian continent into the air masses above the Pacific is found to be highest in the winter and spring seasons. [lxii] Transit times across the Pacific during this period usually range from 5 to 12 days depending on altitude and weather patterns.

Investigation.

In this exercises you will examine routes of transport of pesticides and toxic chemicals other than across the Pacific into the Arctic.

1. Identify the toxic pollutants transported to Hawaii. What did the Mauna Loa Observatory find?
2. Research and list the chemicals transported from mid-western industrial cities into Canada and the Northeast states.
3. Research African Dust being transported into the Southeastern states and the Caribbean.
4. On a map, illustrate these transport patterns.
5. Now choose one of these patterns of transport and elaborate on the chemicals being transported. Are they the same as when they were manufactured, or are they breakdown chemicals? Are they more or less toxic than the parent compounds, or just different?
6. Explore a few (2-3) of these chemicals. What are the exposure effects on humans? What systems do they affect?
7. What are the effects on the environment and other biota?
8. What can you do to reduce your exposure to these toxins?
9. What can you do to lessen the exposure of future generations?



Exercise 5. Airborne Mercury

Background. Heavy metals such as mercury, lead, arsenic, and cadmium are also picked up and transported by air currents. While heavy metals exist in the natural environment, concentrations at some locations in the Arctic are too high to have come from natural releases. Although some heavy metals are essential micronutrients, others are naturally highly toxic and have serious deleterious effects at higher concentrations.[lxiii]

The air around us is one route of exposure. Pollutant transport across the Pacific Ocean, on the mid-latitude westerly winds, is one of many intercontinental and transoceanic pathways of pollutant transport of persistent organic pollutants (POPs), and heavy metals such as mercury. Texas, with 19 coal-fired power plants, releases more mercury into the air than any other state. For every 1,000 lbs of mercury released in the environment, the autism rate rose by 61% and the demand for special education grew by 43%, and that the closer to the source of mercury emissions, the higher the autism rate.[lxiv]

The nation's 1,100 plus coal-fired power plants spew some 400,000 tons/year of lead, mercury, hydrochloric acid, chromium, and arsenic into the air, as well as 60% of the nation's sulfur dioxide (SO2) emissions, and they are second only to automobiles as the largest source of nitrogen oxide (NOx) pollution.[lxv] About 48 tons of mercury rise from these plants into the air each year, more than 40% of all airborne mercury from industry.[lxvi] Globally the load of mercury in heavily industrialized countries is increasing over time, in parallel with increases in neurodegenerative diseases such as autism and Alzheimer's disease.[lxvii]

After pouring through smokestacks and evaporating from water, mercury travels thousands of miles, then falls to earth as rain or snow, or become attached to particles in the air (dust) and sink into streams, lakes, oceans, farm soil or in your home. There bacteria converts it into a more toxic form, methylmercury (known as organic mercury) which is taken up by algae. The algae are part of the food chain, so the methylmercury accumulates up the food chain into humans. Tuna and salmon have a particularly heavy burden of methylmercury. [lxviii] Other studies document POPs and mercury in wildlife and human populations in the Arctic. [lxix]

Investigation.

1. Where does mercury come from? What is it used for?
2. What is methylmercury and how does it differ from elemental mercury?
3. Discuss the toxic effects of mercury exposure to humans and in the environment. Cite exposure cases from your research.
4. Who or what is a "mad hatter"?
5. Discuss the story of the mad hatters in London, England during Great Britain's Industrial Revolution.
6. How does this story relate to mercury exposure and mental disorders?
7. What are the potential effects of inhalation of methylmercury? Do not forget to include sensitive populations such as young children and pregnant mothers.
8. How can you prevent exposure to mercury via inhalitation, absorption or ingestion?

End Notes for Fate and Transport.

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[i] Cone, M., 2005; Silent Snow: The Slow Poisoning of the Arctic; New York: Grove Press. Raloff, J., The Pesticide Shuffle; Science News; 149; p. 174-175. Loganthan, J., and Kannon, K., 1994; Global Organochlorine Contamination Trends: An Overview; Ambio 23; 197-191. Wania, F., and Mackay, D., 1993; Global Fractionation and Cold Condensation of Low Volatility Organochlorine Compounds in Polar Regions; Ambio 22; p. 10-18.
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